

Red Discoloration of Fully Cooked Chicken Products

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Primary Audience: Processors, Quality Assurance Personnel, Researchers

SUMMARY

Internal red discoloration of fully cooked, bone-in chicken products is considered a quality defect because consumers perceive that the meat is undercooked and unsafe for consumption. Sporadic occurrences of discoloration seem to be widespread within the industry, but no data are available to adequately assess the incidence or severity of this problem. Therefore, products typically available to the consumer either directly from the supermarket or indirectly through a wholesaler were evaluated to determine the relative occurrence and severity of internal red discoloration. Commercially fully cooked breasts, thighs, and drums were objectively and subjectively evaluated for internal red discoloration with the following product types: fried chicken from a supermarket deli, rotisserie chicken from a supermarket deli, frozen fried chicken from a supermarket freezer case, and, frozen fried chicken available wholesale as a commodity item. Overall, 11% of products sampled would likely generate consumer complaints or rejection, as 10.6 and 0.4% were scored as extensively or severely discolored, respectively. Of the remaining products, 60.5% had little or no discoloration, and 28.5% showed slight to moderate discoloration. The fried deli product seemed to have less discoloration than the other products tested. Objectively, breasts were less discolored than thighs or drums, and discoloration in the thigh was redder than breast or drum discoloration. The discolored areas in each piece were both darker and redder than nondiscolored (normal) areas within each piece. Red discoloration seems to be a persistent problem at a relatively low level and varies among product types.

Key words: red discoloration, chicken meat redness, cooked chicken survey

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DESCRIPTION OF PROBLEM

Color of poultry meat is extremely important to consumers for initially choosing the product and for evaluating subsequent product quality. There are several types of color defects that affect poultry meat, but one of the most important is the appearance of undercooked meat. Meat pinking, a defect potentially leading to an undercooked appearance, can be affected by factors such as bird age, preslaughter stress, di-

etary intake of nitrates, inhalation of automobile exhaust, or consumption of moldy feed materials [1, 2, 3, 4, 5]. Live birds may also be mishandled during catching or hanging or may be stunned improperly, all of which would increase bruising and hemorrhaging [6, 7]. After slaughter, meat pinkness may be affected by postmortem aging, nitrate or nitrites in water or ice, certain ingredients, or cooking methods [8, 9, 10, 11, 12]. Factors that cause pinking, as well as other poultry meat color issues, have been comprehen-

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sively reviewed [13, 14, 15]. A different type of color problem associated with poultry meat is bone darkening. Bones in cooked meat and the surrounding tissue have a black or burgundy color, from the leaching of bone marrow through the bone after the piece is frozen [16, 17, 18]. Meat pinking and bone darkening may lead to consumer complaints but are less likely to be rejected, unless the meat pinking is severe or bone darkening is noticeably red.

Red discoloration as described in this study, is more intense, localized, and dark red (sometimes bloody), usually found on or in the meat near the bone. Red discoloration is a different phenomenon than meat pinking. It may be more closely related to bone darkening but with considerably more redness. Little direct research is available on this red discoloration defect in poultry meat. Anecdotal evidence from commercial cooking plants suggest that cutting across bones during processing may lead to excessive bone marrow leaching onto the surface of adjacent meat. Experiments have been conducted that evaluated redness of bone-in thighs after cooking to overall doneness of the product. In one study, increased cooking time and temperature decreased the internal redness, but some redness remained even at temperatures of 87.8°C, and yields decreased due to the increased cook temperatures and times [19].

Cooked poultry products showing moderate to severe internal red discoloration often lead to complaints and consumer rejection. Further processors and retailers may lose business due to complaints or customer rejection and could possibly receive increased scrutiny by the USDA or Food and Drug Administration (and potential recall) and eventual insurance claims for alleged illness. A typical scenario could occur as follows: A complaint of undercooked product is received, followed by increased scrutiny of affected product by the processor or retailer, then action is taken that usually involves increasing cooking time or temperature of the product. After a period of time the complaints subside, few or no scientific observations are recorded, and usually no samples are collected or analyses conducted. The actual cause, resulting incidence and severity, and resolution of the problem are not objectively described nor are future events prevented. The question of whether the internal

red discoloration is a sporadic, acute problem with a specific, recurring cause, or a chronic problem exacerbated by occasional complaints, or a combination of factors remains unknown. Therefore the purpose of this experiment was to evaluate commercially available, bone-in, fully cooked products to determine a relative baseline of the incidence and severity of internal red discoloration.

MATERIALS AND METHODS

Four different types of fully cooked, bone-in commercial chicken products were sampled for subjective and objective red discoloration. Products included fresh, 8-piece cut-up, fried, breaded, chicken prepared at and obtained from the supermarket deli (FRIED); fresh, whole, rotisserie-cooked, chicken prepared at and obtained from the supermarket deli (ROTIS); frozen, 10- to 12-piece cut-up chicken, fried and boxed for retail sale at the manufacturer and obtained from the supermarket frozen foods section (BOXED); and frozen 8-piece cut-up, par-fried, oven cooked, and bulk packed for commodity sales prepared at and obtained from the manufacturer (COMOD). Further product descriptions are shown in Table 1.

On each of 3 d (approximately 1 wk apart), 4 separate containers of each of the FRIED, ROTIS, and BOXED products were bought from the same local supermarket. On each of 2 separate d (approximately 3 wk apart) 2 cases of bulk COMOD product were obtained from the manufacturer. The FRIED and ROTIS products had been refrigerated overnight after preparation at the supermarket and were allowed 1 h to warm to room temperature (approximately 21°C). The frozen BOXED and COMOD products were allowed 3 h for warming. The ROTIS products were manually cut into 8 pieces. [Note: wings from all products were discarded because there was not sufficient flat muscle surface for objective color evaluation using a colorimeter. Not all FRIED containers held an 8-piece cut-up chicken as advertised. For example, on 1 d, one container held 3 drumsticks and only 1 thigh; on another day 3 of the 4 containers held only split breasts (4 each) and no other pieces. The BOXED containers held various pieces of multiple cut breasts and sometimes split thighs.] All products were then divided into breasts, thighs,

TABLE 1. Abbreviations and product descriptions of the fully cooked, bone-in chicken items selected for red discoloration evaluation

| Abbreviation | Piece cut | Cook method | Packed as | Form | Market | Available from |
|--------------|-----------------|--------------|----------------------|--------|-----------|--------------------------|
| ROTIS | Whole bird | Rotisserie | Individual bird | Fresh | Retail | Supermarket deli |
| FRIED | 8 Pieces | Fry | Individual bird | Fresh | Retail | Supermarket deli |
| BOXED | Multiple pieces | Fry | Individual 25-oz box | Frozen | Retail | Supermarket freezer case |
| COMOD | 8 Pieces | Parfry, oven | Bulk case | Frozen | Wholesale | Manufacturer |

and drums, which were manually broken open to separate muscle surfaces from bones and to reveal any internal muscle discoloration. Triplicate colorimeter measurements (averaged to one mean) were taken from a section of single contiguous muscle that showed the most discoloration, plus an adjacent nondiscolored area (control) using a Minolta colorimeter [20] with 10-mm aperture. CIE L^* and a^* values were recorded (lightness and redness, respectively). Subjective discoloration scores were recorded at the same time by one observer, on a scale of 1 to 4 (where 1 = little or no discoloration, 2 = slight to moderate, 3 = moderate to extensive, and 4 = severe discoloration) based on the size of the discolored area and the amount of visible redness [21]. Data were separated by piece type (breast, drum, and thigh) and analyzed using SAS software procedures [22] to determine discoloration differences between product types and between control and discolored in the same piece [23].

RESULTS

Objective Color

The lightness (L^*) values of the control (normal) areas of breast pieces were significantly affected ($P < 0.01$) by product type (Table 2). COMOD lightness (79.31 ± 0.48) was higher than BOXED (71.04 ± 1.84), although neither was different from FRIED (76.77 ± 0.78) or ROTIS (76.60 ± 0.43), which were not different from each other. Product type had no effect on lightness values for discolored areas of the breast.

The control and discolored areas of thighs were affected by product type. In the control areas, COMOD and FRIED lightness values (72.50 ± 0.40 and 70.71 ± 0.87 , respectively) were greater than BOXED (65.66 ± 1.35), which was not different than ROTIS (68.62 ± 0.70).

ROTIS and FRIED were also not different from each other. Discolored area lightness was highest for COMOD (60.98 ± 1.27) and FRIED (56.70 ± 2.13), and COMOD was greater than ROTIS (52.96 ± 1.62) or BOXED (51.14 ± 2.64).

Drum lightness values from control areas were affected by product type, as COMOD (69.04 ± 0.47) had a higher value than the other 3 products. BOXED values (65.03 ± 0.84) were greater than ROTIS (60.58 ± 0.96), which was not different than FRIED (63.40 ± 0.74). There were no differences among products for discolored area lightness values for drums.

Breast, thigh, and drum lightness values for all products were higher for control areas than discolored areas. The overall difference between control and discolored areas, by piece, was approximately 10 units for breasts, 14 units for thighs, and 11 units for drums. Thigh meat seemed to be more affected (darker) in discolored areas than similarly defined areas of the breast or drum.

Redness (a^*) values for breast, drum, and thigh control and discolored areas are presented in Table 3. Breast redness values for control areas showed that FRIED (1.16 ± 0.25) and BOXED (1.66 ± 0.43) were not different and were lower than COMOD (3.19 ± 0.50) and ROTIS (3.06 ± 0.26), which were not different from each other. Similarly for the discolored areas, FRIED (4.39 ± 0.54) and BOXED (4.15 ± 0.53) were not different from each other for redness but were lower than COMOD (7.13 ± 0.58) and ROTIS (8.07 ± 0.75), which were not different.

Thigh redness values showed no differences due to product type for control areas. Discolored areas also were not affected by product type. Redness values for drums were not different for control areas. In the discolored areas ROTIS (6.15 ± 0.56) was lower than BOXED ($9.03 \pm$

TABLE 2. Means and SEM for CIE L* (lightness) values of control and discolored areas of breast, thigh, and drum pieces from 4 fully cooked, bone-in poultry products (FRIED or deli fried; ROTIS or deli rotisserie; BOXED or fried and frozen retail; and COMOD, or commodity fried bulk packaged)

| Piece | Product | L* | | Probability | n |
|--------|---------|----------------------------|----------------------------|-------------|----|
| | | Control | Discolored | | |
| Breast | FRIED | 76.77 ^{ab} ± 0.78 | 66.45 ± 1.56 | <0.0001 | 30 |
| | ROTIS | 76.60 ^{ab} ± 0.43 | 64.72 ± 1.13 | <0.0001 | 24 |
| | BOXED | 71.04 ^b ± 1.84 | 63.54 ± 2.20 | <0.0001 | 41 |
| | COMOD | 79.31 ^a ± 0.48 | 69.63 ± 0.94 | <0.0001 | 20 |
| Thigh | FRIED | 70.71 ^{ab} ± 0.87 | 56.70 ^{ab} ± 2.13 | <0.0001 | 17 |
| | ROTIS | 68.62 ^{bc} ± 0.70 | 52.96 ^b ± 1.62 | <0.0001 | 24 |
| | BOXED | 65.66 ^c ± 1.35 | 51.14 ^b ± 2.64 | 0.0004 | 16 |
| | COMOD | 72.50 ^a ± 0.40 | 60.98 ^a ± 1.27 | <0.0001 | 20 |
| Drum | FRIED | 63.40 ^{bc} ± 0.74 | 51.86 ± 1.82 | <0.0001 | 19 |
| | ROTIS | 60.58 ^c ± 0.96 | 52.27 ± 1.55 | <0.0001 | 24 |
| | BOXED | 65.03 ^b ± 0.84 | 51.11 ± 1.63 | <0.0001 | 19 |
| | COMOD | 69.04 ^a ± 0.47 | 57.41 ± 0.94 | <0.0001 | 20 |

^{a-c}Means within column and piece type with no common superscripts differ significantly (*P* < 0.01).

0.83) or COMOD (9.21 ± 0.48), and FRIED (8.09 ± 0.70) was not different from any of the other products.

Comparison of control areas to discolored areas for all product types within breast and thigh pieces showed that discolored areas were significantly redder. This finding was also true for drums, except for ROTIS product, where the control value (5.14 ± 0.34) was not different from the discolored value (6.15 ± 0.56).

Subjective Scores

Product type had no significant effect (*P* < 0.01) on the means of subjective scores across piece types. Piece type did affect the scores, as breast had a lower score (1.24 ± 0.06) than thigh (1.75 ± 0.10) or drum (1.72 ± 0.08), which were not different from each other.

Subjective scores were also categorized and based on total percentage of the 1, 2, 3, or 4 scores by product type and piece (Figure 1). This

TABLE 3. Means and SEM for CIE a* (redness) values of control and discolored areas of breast, thigh, and drum pieces from four fully-cooked, bone-in poultry products (FRIED or deli fried; ROTIS or deli rotisserie; BOXED or fried and frozen retail; and, COMOD, or commodity fried bulk packaged)

| Piece | Product | a* | | Probability | n |
|--------|---------|--------------------------|---------------------------|-------------|----|
| | | Control | Discolored | | |
| Breast | FRIED | 1.16 ^b ± 0.25 | 4.39 ^b ± 0.54 | <0.0001 | 30 |
| | ROTIS | 3.06 ^a ± 0.26 | 8.07 ^a ± 0.75 | <0.0001 | 24 |
| | BOXED | 1.66 ^b ± 0.43 | 4.15 ^b ± 0.53 | <0.0001 | 41 |
| | COMOD | 3.19 ^a ± 0.50 | 7.13 ^a ± 0.58 | <0.0001 | 20 |
| Thigh | FRIED | 3.70 ± 0.35 | 7.26 ± 0.64 | <0.0001 | 17 |
| | ROTIS | 4.51 ± 0.48 | 10.70 ± 0.87 | <0.0001 | 24 |
| | BOXED | 3.51 ± 0.59 | 8.65 ± 0.92 | 0.0008 | 16 |
| | COMOD | 4.45 ± 0.55 | 8.47 ± 0.65 | <0.0001 | 20 |
| Drum | FRIED | 4.32 ± 0.46 | 8.09 ^{ab} ± 0.70 | 0.0004 | 19 |
| | ROTIS | 5.14 ± 0.34 | 6.15 ^b ± 0.56 | 0.0715 | 24 |
| | BOXED | 4.43 ± 0.45 | 9.03 ^a ± 0.83 | 0.0002 | 19 |
| | COMOD | 5.38 ± 0.42 | 9.21 ^a ± 0.48 | <0.0001 | 20 |

^{a,b}Means within column and piece type with no common superscripts differ significantly (*P* < 0.01).

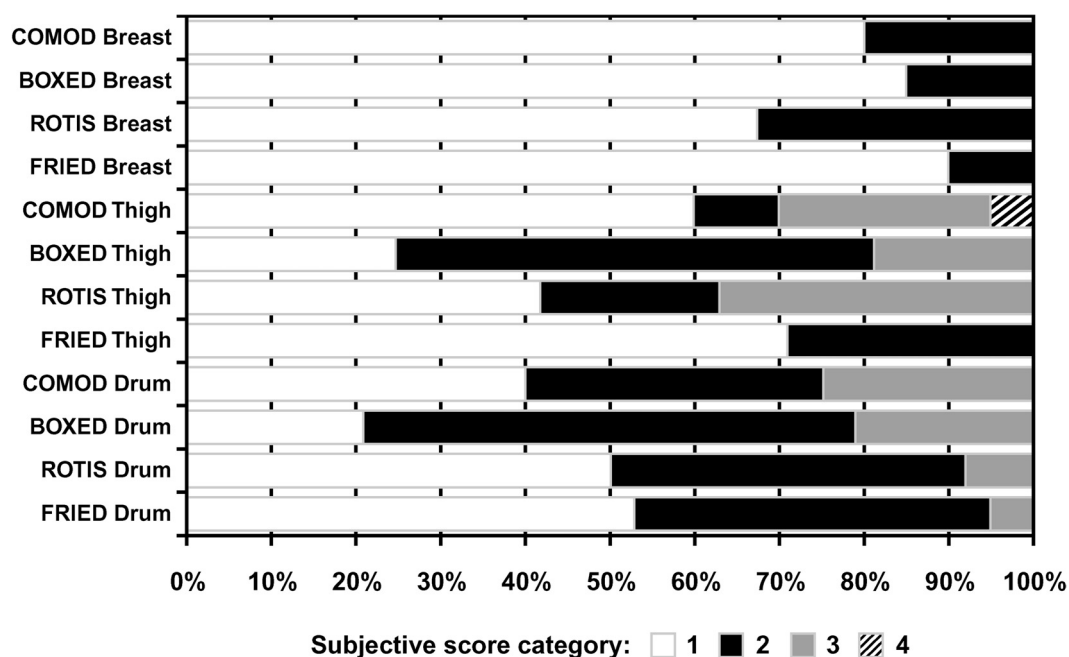


FIGURE 1. Percentage of subjective red discoloration scores by category (where 1 = no or slight discoloration to 4 = severe discoloration) for product types (FRIED or deli fried; ROTIS or deli rotisserie; BOXED or fried and frozen retail; and COMOD, or commodity fried bulk packaged) and piece types (breast, thigh, or drum).

approach produced a different pattern of results than shown by the means, as both piece type and product type affected the score categories. Breasts across product types show less total discoloration, and less severe discoloration than thighs or drums. Within piece types, product types appear to differ in regard to both overall and severity of discoloration. Overall, when the total number of pieces sampled (274) was placed into the respective categories, 166 were category 1 (60.5%); 78 were category 2 (28.5%); 29 were category 3 (10.6%), and, 1 was category 4 (0.4%).

DISCUSSION

Different product types surveyed in this study had varying levels of discoloration, as evidenced by the lightness and redness values. Subjective scores, when placed on a percentage basis within categories and piece types, also indicated differences due to product types. In a previous experiment, several thigh products obtained commercially varied in the amount of internal redness [24]. Breasts prepared and cooked using two different methods show different bone discoloration [17]. Whether due to inherent differ-

ences in the meat itself, or due to processing variables, different products do differ with regard to internal red discoloration.

Piece types exhibited differences with respect to red discoloration. Means of subjective scores showed that breasts were less discolored than thighs or drums. Previous research has shown pieces differ in initial color, in that breasts are lighter and less red than thighs [18]. This finding may be due to breasts having a lower proportion of total bone area to muscle mass, fewer large calcified bones, a lower proportion of blood vessels per muscle mass (less hemoglobin), or lower myoglobin content than thighs or drums. Prior research suggests that leakage of bone marrow onto or into the surrounding muscle tissue, mainly due to freezing, may discolor meat [16, 18]. However, the 2 frozen products evaluated (COMOD and BOXED), exhibited different patterns of discoloration as determined by thigh lightness, breast redness, and thigh subjective scores. Therefore, freezing alone did not account for variation in discoloration among product types.

The total average difference in redness values between control and discolored areas were

larger for thighs (14 units) than breasts or drums (10 and 11 units, respectively), indicating thigh discoloration was redder than breast or drum discoloration. Possibly plant error from cutting off the ends of the femur introduced more marrow into the meat or the ordinary leakage from the femur produced more of a reddening effect in the thigh than did bones in the breast or drum.

Differences of lightness between control and discolored areas for all 12 of the product and piece type combinations were noted, and for redness for 11 of 12 product and piece type combinations. This result was expected, because the definition of discoloration for this study was a redder, darker area of the meat, which was actively sought for objective and subjective evaluation.

The subjective score data showed that 89% of all product pieces samples were category 1 or 2, which would probably be acceptable to the majority of consumers. Eleven percent of products tested were placed in category 3 or 4, which would tend to be rejected by the majority of consumers. Although products and pieces within product varied in regard to discoloration, a measurable level of discoloration seems to occur across poultry products. The evidence from this survey appears to support the hypothesis that cooked poultry items tend to have persistent but relatively low levels of red discoloration, although some products may be more susceptible than others.

CONCLUSIONS AND APPLICATIONS

1. Discoloration varied among product types as determined by the varying objective lightness and redness values, whereas subjective scores categorized by piece and product showed that the fresh fried deli product (FRIED) was less discolored than other products.
 2. Piece type had an effect on discoloration, as breasts were less discolored than thighs or drums, and thigh discoloration seems to be redder than breasts or drums.
 3. Severe discoloration, as determined by subjective evaluation, occurred in 0.4% of product evaluated, with 10.6% of products showing extensive discoloration. Therefore, 11% of products evaluated could lead to complaints or rejection.
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21. Pieces were observed using ambient fluorescent light and were categorized as follows: 1) no or very slight discoloration. Would not generate consumer complaints. 2) Slight to moderate area of discoloration (less than 10 cm), with little visible redness. 3) Moderate to extensive discolored area (at least 10 cm) with some visible redness. Consumer complaints likely, and rejection possible. 4) Severe, large visible discolored area (at least 15 cm), with intense redness appearing as free-flowing blood. Would be considered inedible by most consumers.
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